steering angle of the steering wheel, the driving condition, and the like. In this manner, the steering feeling and the steerability can be improved.

While the present invention has been disclosed in terms of the preferred embodiments in order to facilitate better understanding of the invention, it should be appreciated that the invention can be embodied in various ways without departing from the principle of the invention. Therefore, the invention should be understood to include all possible embodiments which can be embodied without departing from the principle of the invention set out in the appended claims.

Additionally, the disclosure of Japanese Patent Application No. 2002-246282 filed on August 27, 2002 including the specification, drawing and abstract is incorporated herein by reference in its entirety.

WHAT IS CLAIMED IS:

1. An electric power steering apparatus having a steering system capable of flexibly setting a relationship between a steering angle of a steering wheel and a wheel angle of a tire, comprising:

a first motor for controlling a steering reaction force exerted on said steering wheel;

an on-center region determination section for determining whether said steering wheel is in a position of an on-center

region;

a tire reaction force torque detection section for detecting tire reaction force torque transferred from said tire; and

a control section for calculating steering torque based on said tire reaction force torque detected by said tire reaction force torque detection section and a torque gain, and for controlling said first motor to exert said steering reaction force corresponding to said calculated steering torque on said steering wheel,

wherein said control section sets said torque gain in case of determining that said steering wheel is in the position of said on-center region larger than said torque gain in case of determining that said steering wheel is not in the position of said on-center region.

2. The electric power steering apparatus according to claim 1, further comprising:

a steering angle detection section for detecting said steering angle of said steering wheel; and

a second motor for controlling said wheel angle of said tire,

wherein said control section calculates said wheel angle based on said st ering angle detected by said steering angle detection section and an angle gain as a fix d value, and controls

said second motor so that said wheel angle of said tire corresponds said calculated wheel angle.

3. An electric power steering apparatus having a steering system capable of flexibly setting a relationship between a steering angle of a steering wheel and a wheel angle of a tire, comprising:

a first motor for controlling steering reaction force exerted on said steering wheel;

a second motor for controlling said wheel angle of said tire;

a steering angle detection section for detecting said steering angle of said steering wheel;

an on-center region determination section for determining whether said steering wheel is in a position of an on-center region;

a tire reaction force torque detection section for detecting tire reaction force torque transferred from said tire; and

a control section for calculating a steering torque based on said tire reaction force torque detected by said tire reaction force torque detection section and a torque gain, for controlling said first motor to exert said steering reaction force corresponding to said calculated steering torque on said steering wh el, for calculating said wh el angle based on said

steering angle detected by said steering angle detection section and an angle gain, and for controlling said second motor so that said wheel angle of said tire corresponds to said calculated wheel angle,

wherein said control section sets said torque gain in case of determining that said steering wheel is in the position of said on-center region larger than said torque gain in case of determining that said steering wheel is not in the position of said on-center region, and sets said angle gain in case of determining that said steering wheel is in the position of said on-center region smaller than said angle gain in case of determining that said steering wheel is not in the position of said on-center region.

4. An electric power steering apparatus having a steering system capable of flexibly setting a relationship between a steering angle of a steering wheel and a wheel angle of a tire, comprising:

a first motor for controlling steering reaction force exerted on said steering wheel;

a second motor for controlling said wheel angle of said tire;

a steering wheel angle detection section for detecting said st ering angle of said steering whe l;

an on-center region determination section for determining

whether said steering wheel is in a position of an on-center region;

a tire reaction force torque detection section for detecting tire reaction force torque transferred from said tire; and

a control section for calculating steering torque based on said tire reaction force torque detected by said tire reaction force torque detection section and a torque gain, controlling said first motor to exert said steering reaction force corresponding to said calculated steering torque on said steering wheel, for calculating said wheel angle based on said steering angle detected by said steering angle detection section and an angle gain, and controlling said second motor so that said wheel angle of said tire corresponds to said calculated wheel angle,

wherein said control section sets said torque gain in case of determining that said steering wheel is in the position of said on-center region smaller than said torque gain in case of determining that said steering wheel is not in the position of said on-center region, and sets said angle gain in case of determining that said steering wheel is in the position of said on-center region larger than said angle gain in case of determining that said steering wheel is not in the position of said on-center region.

5. The electric power steering apparatus according to claim 1, 2 or 4, wherein said on-center region determination section determines that said steering wheel is in the position of said on-center region, in case that an absolute value of said steering reaction force corresponding to said calculated steering torque is a predetermined threshold value or smaller.

6. The electric power steering apparatus according to claim 1, 2 or 4, further comprising:

a steering torque detection section for detecting said steering torque of said steering wheel,

wherein said on-center region determination section determines that said steering wheel is in the position of said on-center region, in case that an absolute value of said steering torque detected by said steering torque detection section is a predetermined threshold value or smaller.

7. The electric power steering apparatus according to claim 1, 2 or 4, wherein said on-center region determination section determines whether said steering wheel is in the position of said on-center region, based on a lateral acceleration of a vehicle, said tire reaction force, or said steering angle.

8. The electric power steering apparatus according to claim 7, wherein said control section sets said angle gain or said

torque gain in response to a vehicle condition amount indicating a driving condition of said vehicle.

9. The electric power steering apparatus according to claim 1, 2 or 4, wherein said control section sets said angle gain or said torque gain in response to a vehicle condition amount indicating a driving condition of said vehicle.

10. The electric power steering apparatus according to claim 8, wherein said vehicle condition amount includes at least a vehicle speed.

11. The electric power steering apparatus according to claim 10, wherein said control section determines driving stability of said vehicle based on a distance on a stability determination map, and changes said angle gain and said torque gain in response to said determination result, said stability determination map defining a relationship between a yaw rate and a skid angle of said vehicle, said distance being obtained by connecting between a coordinate point and an origin on said stability determination map, said coordinate point being identified by the skid angle and the yaw rate.

12. The electric power steering apparatus according to claim 1, 2 or 4, wherein said control section determines driving

stability of said vehicle based on a distance on a stability determination map, and changes said angle gain and said torque gain in response to said determination result, said stability determination map defining a relationship between a yaw rate and a skid angle of said vehicle, said distance being obtained by connecting between a coordinate point and an origin on said stability determination map, said coordinate point being identified by the skid angle and the yaw rate.

13. The electric power steering apparatus according to claim 12, wherein said control section estimates a road surface friction condition, and changes said angle gain and said torque gain in response to said estimation result.

14. The electric power steering apparatus according to claim 1, 2 or 4, wherein said control section estimates a road surface friction condition, and changes said angle gain and said torque gain in response to said estimation result.

15. The electric power steering apparatus according to claim 1, 2 or 4, wherein said control section sets an upper limit value and a lower limit value with respect to at least either said angle gain or said torque gain.

16. The electric power steering apparatus according to claim

1, 2 or 4, wherein said control section sets an upper limit value and a lower limit value with respect to at least either said angle gain or said torque gain.